The Distribution of Brood Ten of the Periodical Cicadas in New Jersey in 1970[1]

John B. Schmitt
Rutgers—The State University, New Brunswick, N. J.

Received for Publication April 26, 1974

Abstract: The last thorough study of the distribution of Brood X of the periodical cicadas in New Jersey (*Magicicada* spp.) was made in 1902. Data collected on the distribution of the 1970 emergence indicates a disappearance since 1902 from the following localities: Mercer County except Princeton; eastern Somerset County; Prospertown-Colliers Mills, Ocean County; Jacobstown-Ellisdale, Burlington County; Cherry Hill Township, Camden County; Salem and Woodstown, Salem County; and Shiloh in Cumberland County. Hitherto unreported populations were found on Lower Powhatcong Mountain, Warren County; near Middletown, Monmouth County; and Quinton and Alloway in Salem County. Forty populations were found in Hunterdon County, west and south of the South Branch of the Raritan River. The chief factors in the disappearance of the insect since 1902 appear to have been the destruction of woodlands, forest fires, and urbanization. The possibility that forest losses caused by the gypsy moth may play a part in the loss of periodical cicada populations is suggested.

INTRODUCTION

The periodical cicadas are well known for the fact that adults of the six species emerge from the soil after either 13 or 17 years of nymphal existence. Alexander and Moore (1962) provide a table showing past emergence dates since 1621 and predicting the future emergence dates until the year 2028, of all known broods of both the 13-year and the 17-year species. A "brood" may be defined as consisting of all the populations of the species complex (either 13-year or 17-year) emerging in any year. Since the years of emergence follow a well-defined cycle, the various generations of a brood may thus be recognized and identified by a Roman numeral. In New Jersey, six broods of the 17-year species were known to exist in the early decades of this century (Weiss, 1916; Davis, 1926). As predicted, adults of Brood X appeared in 1970. The preceding years of emergence of Brood X in this century were 1902, 1919, 1936 and 1953.

Acknowledgments: At various points in this paper, the writer has endeavored to recognize the individuals whose generous participation made possible a more complete or more satisfying solution of some questions regarding Brood X in 1970. The contributions of two individuals, however, should be especially acknowledged. I am particularly indebted to Dr. Lyle E. Hagmann and Mr. Joseph D. Stewart of the Department of Entomology at Rutgers for their very considerable help.

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Cook College, Rutgers University—The State University of New Jersey, Department of Entomology and Economic Zoology, New Brunswick, New Jersey 08903.

In 1969 the writer reviewed the literature which had been published on the distribution of Brood X in New Jersey since Smith (1903) described its distribution in the emergence of 1902. Weiss (1916) added nothing to Smith's data. Marlatt (1907) also described the 1902 emergence, and lists several counties and localities not cited by Smith. However, Smith was aware of these additions through correspondence with Marlatt, and in his 1903 report comments on them substantially as follows:

Middlesex County. Marlatt cited a report from Deans which stated that the cicadas occurred "by the millions." Smith says he searched the area and found no trace of them.

Morris County. Marlatt reported them from Boonton. Smith searched through Morris County, and especially Boonton, without being able to verify the record.

Gloucester County. Marlatt's record, according to Smith, was based on a newspaper report of an occurrence in the Swedesboro-Harrisonville area. Smith found no trace of the insect in Gloucester County. Although Smith failed to confirm Marlatt's records, the writer made a special effort to find these populations in 1970, without success.

Davis (1926) considerably extended the list of counties in New Jersey over that provided by Smith for Brood X. However, a careful reading of Davis' paper shows that he based his additions solely on the annual report of the Department of Entomology of the New Jersey Agricultural Experiment Station for 1919 (Headlee, 1919). Unfortunately, these records did not mean that actual specimens were received or identified, but only that correspondence concerning the cicada was received from residents in the various counties. Much of this correspondence was dated in months of the year when the insects were underground, and it seems very probable that such correspondence was prompted by newspaper accounts predicting the forthcoming emergence of the cicadas. However, as in the case of Marlatt's records, an intensive effort was made in 1970 to determine whether Brood X exists in the disputed counties. No literature could be found regarding the emergences of 1936 and 1953 which extended the distribution described by Smith in the 1902 emergence.

The writer decided to undertake a thorough study of the 1970 emergence to learn what, if any, changes in distribution had taken place since 1902, a period of time representing four cicada generations. It was obvious that some measure of public assistance in finding local populations would be valuable. Accordingly, in the spring of 1970 news stories alerting the public to the coming of the cicadas were distributed to the newspapers of the State through the courtesy of the Communications Center of our State Cooperative Extension Service. The writer also sent a personal letter to each county agricultural agent asking for records of cicada emergence and explaining the purpose of the study. A similar appeal was sent to the superintendent of each county mosquito control agency. Col-

leagues in the Department of Entomology and Economic Zoology at Rutgers were also reminded of the predicted emergence and their cooperation sought. During and after the emergence period, the writer made a number of field trips to check on distribution, and a record of adult cicada distribution in 1970 was thus obtained which the writer believes is fairly complete. This paper will compare that record with the observations of Smith (1903). It should perhaps be noted that in the study of these cicadas, it is the existence of large local populations that is significant, not the occurrence of individuals separated from a large population. Such large local populations typically contain many thousands of individuals of both sexes, and their presence is advertised by the daytime din of their song and by oviposition injury to deciduous trees.

OBSERVATIONS

Figure 1 summarizes the distribution of Brood X in New Jersey in 1902 (Smith's data) and in 1970. Isolated localities known to Smith are marked by circles. If cicadas appeared in a given locality in 1970 also, the circle is solid; if cicadas could not be found in 1970, the circle is open. The squares represent populations seen in 1970 in localities apparently not known to Smith. The numeral accompanying each locality marker serves to identify the locality in the text.

The large, lightly-shaded area in the central-western part of the map indicates the general distribution of Brood X in 1902 in that area. The smaller, heavily-shaded area represents the general distribution of Brood X in the area in 1970. The distribution of individual populations in 1970 in most of that area (Hunterdon County and adjoining areas) is shown in Figure 2 as numbered circles. These localities are also geographically identified by number in the text.

The isolated populations indicated in Figure 1 will be identified first. In 1902 Smith reported, from correspondence, a population at Roxbury, in Warren County. His map shows it extending inland from the Delaware, a few miles south of Belvidere. In 1970, the writer did find a small population at the western end of the area indicated by Smith, near Harmony Station (Fig. 1, 1). Roxbury itself is at the northern end of Scott's Mountain. No cicadas were found at Roxbury, but near the village of Montana, a few miles south, they were very abundant (Fig. 1, 2).

Other Warren County populations were observed in 1970 at Stewartsville and New Village. These localities are part of the Lower Powhatcong Mountain forested area (Fig. 1, 3). Apparently Smith did not know of this locality; neither his text nor his map indicates it. Smith did list Carpentersville, Warren County, and a few cicadas were found there. However, the Delaware River at this point represents a gap in the woodland of no more than fifty yards. On the Pennsylvania side there was a large population (Fig. 2, 50); probably the cicadas seen at Carpentersville were only strayed individuals from the Pennsyl-

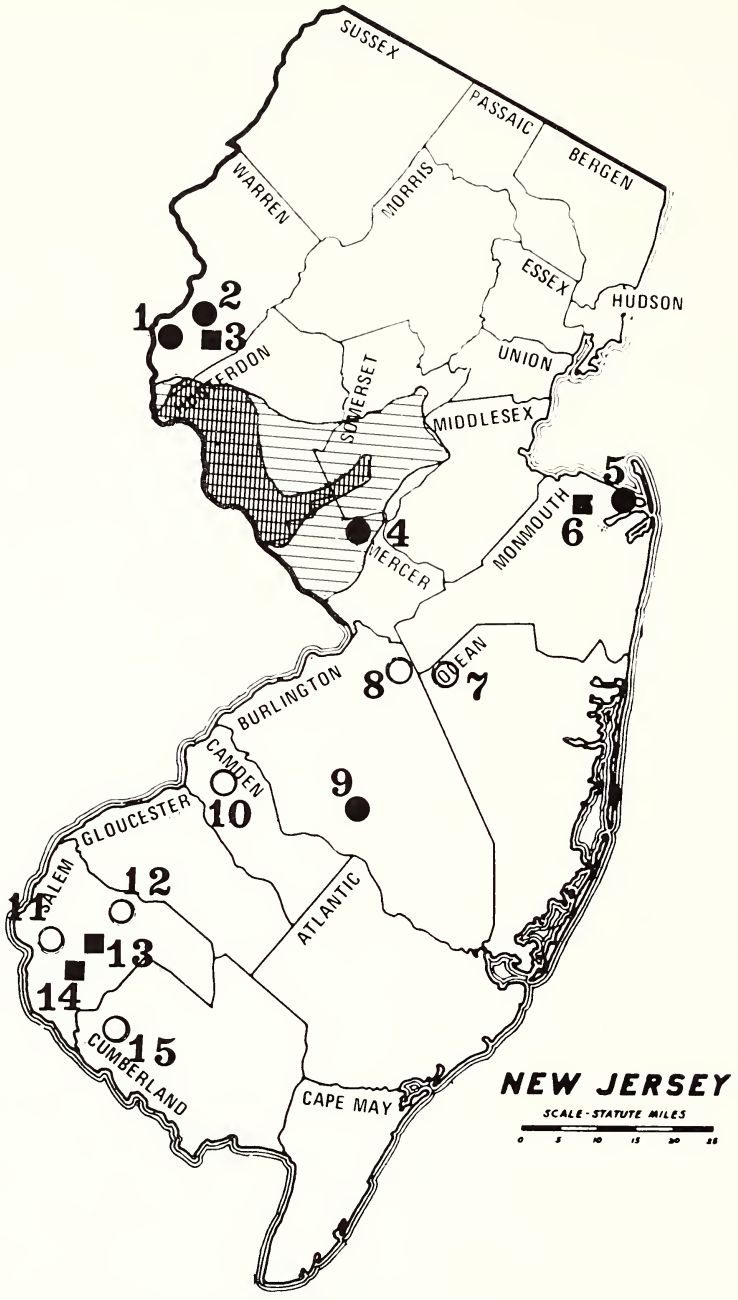

FIG. 1. Map of New Jersey showing distribution of Brood X in 1902 and 1970. See text for details.

vania population. Finesville, also in Warren County, is on the border of the great Hunterdon distribution (Fig. 2, 15).

Sussex County, just north of Warren, is one of the counties cited by Davis (1926) on the basis of the Headlee report (1919). Since it is heavily forested with oak, particular attention was given to the area. County agent John W. Raab, at the request of the writer, spent considerable effort in inquiries and travel, without finding a single population. The writer toured the localities cited by Headlee without uncovering any evidence of cicadas, and no correspondent provided knowledge of a single population. Neither could any resident be found who remembered ever hearing or seeing the insects within the county. Similar efforts in both Morris and Passaic Counties were equally unsuccessful. Brood II is well known to residents of these two counties, but Brood X is not. The County agents of both of these counties, and of Bergen, Union and Essex also could not find a single instance of Brood X, nor could the writer.

As Figure 1 shows, the locality of Princeton (Fig. 1, 4) was included in the general distribution of cicadas in Mercer County in 1902. Smith found the insects to occur abundantly as far south as the Pennsylvania Railroad main line, and westward along that line to Lawrence Station. He concluded that the cicadas were "pretty generally distributed" in Mercer County "except in the extreme south." In 1970, Mr. Charles M. Holmes, senior county agent, supplemented the writer's observations, and was unable to find any cicadas in Mercer County other than the large population on the western edge of Princeton Borough, and along the Mercer-Hunterdon line (Fig. 2, 38, 42). Also, no populations could be found in either Somerset or Middlesex County representing the former eastward extension of the great central area shown in Fig. 1. The only Somerset populations found were on the Sourland Mountain ridges, to be described later.

In Monmouth County, a population in the Navesink Highlands (Fig. 1, 5) had been described by Smith. In 1970, its decendents were very abundant in the same locality, and as the area has apparently changed very little during this century, the insects were probably nearly as abundant as they were in 1902. Individual cicadas were found in Fair Haven, separated from the Navesink Highlands population by about one-half mile of open water, but as no evidence of emergence could be found at Fair Haven, the writer assumes that these specimens were strays from the Highlands population. A second population was found in Monmouth County near Middletown, in the low wooded hills known as the Telegraph Hill formation (Fig. 1, 6). Smith apparently did not know of this colony, located about eight miles from the Navesink Highlands population.

Smith recorded a colony in 1902 in the northwestern corner of Ocean County, between Collier's Mills and Prospertown (Fig. 1, 7). In 1970 no trace could be found of that colony. This area is heavily wooded, with few access roads or human inhabitants. Searches and inquiries in both this area and in the nearby town of New Egypt failed to provide any evidence of the cicadas. It therefore is

probable that this colony has perished. One possible explanation is the fact that the area between Collier's Mills and Prospertown has been devastated by a number of very severe forest fires since 1902. The resulting tree loss might have destroyed the cicadas. However, the apparent disappearance of another population reported by Smith in nearby Burlington County, of which no descendents could be found in 1970, could not be accounted for. Smith reported (from correspondence) a population between Jacobstown and Ellisdale (Fig. 1, 8). Unable to find the cicadas himself, the writer enlisted the aid of Mr. Daniel Kensler, who had been the county agricultural agent in Burlington County for almost 40 years. Despite strenuous efforts on his part, no trace of this colony, either in 1970 or in the past, could be found; either it has become extinct, or Smith's correspondent was in error.

A second locality in Burlington County was described by Smith from the vicinty of Indian Mills. The writer was unable to find any trace of the insects or reports of them, and he is indebted to Dr. Lyle E. Hagmann for finally discovering them. They were found about halfway between Indian Mills and Tabernacle, about one mile east of Route 206 (Fig. 1, 9). The precise location was scaled from a Geological Survey map as 39°48′45″ N and 74°42′30″ W. It is a large colony, as more than 100 acres of trees showed evidence of oviposition.

The only colony of Brood X in Camden County in 1902 was recorded by Smith from Delaware Township, since renamed "Cherry Hill" Township. This area is now highly urbanized. No trace of the colony could be found in 1970, either by the county agent or by the writer. It is probable that the destruction of woodlands since 1902 has destroyed this colony.

As regards Gloucester County, Smith mentions correspondence with Marlatt, who, he says, sent him newspaper reports of the insects near Swedesboro and in the woods between Harrisonville and Swedesboro. In 1970, however, no trace of either of these colonies could be found.

Smith reported two colonies from Salem County in 1902. One of these was described by a correspondent from the town of Salem as "occupying a large tract of timber land which is, unfortunately, gradually becoming exterminated" (Fig. 1, 11). A second colony was described as being near Yorktown (Fig. 1, 12). Mr. Robert Gardner, the county agent in Salem County, became keenly interested in the matter of cicada distribution, and expended a great deal of effort in trying to find populations in 1970. Only two were found. One of these inhabited a woodland near the "Happy Hill" Nursery, Alloway (Fig. 1, 13), and the other was discovered near Quinton (Fig. 1, 14). No trace of the Yorktown colony could be found (Yorktown is about five miles from Alloway). Whether either of the two populations that were found represents the Salem colonies described by Smith is uncertain because of the vagueness of Smith's record, but if the locality was near either Alloway or Quinton, it is perhaps odd

that his correspondent did not use those names, as both communities are old and well-known localities.

Smith reported a single record in 1902 from Cumberland County, in the vicinity of the village of Shiloh (Fig. 1, 15). No trace could be found of this colony in 1970. Here again the writer was very fortunate in the fact that Mr. Kenneth E. Pickett, the county agent of Cumberland County, has lived most of his life in Shiloh and took a keen interest in the matter. Despite all his efforts, he could not find any trace of the Shiloh colony. No other evidence of Brood X in Cumberland could be found by Mr. Pickett or the writer.

Turning to the northwestern area of the state, Smith in 1902 found Brood X existed from just north of Trenton along the Delaware River upstream to a point just south of Phillipsburg in Warren County (Fig. 1). Eastward, the cicadas were found by Smith as far east as Bound Brook. The extent of Brood X distribution in Warren and Mercer Counties has already been considered. The disappearance of the cicadas from their eastern range in Somerset County is indicated in Figure 1.

In Hunterdon County, Smith described the insect in 1902 as "generally present from the Delaware River east to the line of the Central Railroad of New Jersey, and from the Mercer County line north to the Warren County line." The 1970 emergence in Hunterdon was found to be concentrated in three well-defined physiographic areas:

1. The Musconetcong Mountain and ridge area: populations numbered 1 through 21 (Fig. 2). This is a mountain of granitoid gneiss of Precambrian age and is heavily forested. Just south of the mountain in Union and Alexandra townships, there is a forested ridge area of rubbly, glaciated soils derived from the gneiss. These forests were also heavily populated by the cicadas.

2. The Hunterdon Plateau; populations numbered 24 through 30. This is an area of hard sandstone and argillite west of Flemington, about 8 miles wide at Baptistown. The southern portion of the plateau is heavily wooded, primarily because poor soil drainage tends to discourage agriculture, and it is this area which supports the cicadas.

3. The Sourland Mountain; populations numbered 33 through 42. This is a ridge of crystalline rocks, mostly diabase, which extends from the Delaware River to the vicinity of Belle Meade in Somerset County, a distance of about 16 miles. Its western part is a series of forested hills, but its eastern area, which extends into Somerset County, is a continuous plateau. Much of the land is wooded because of steep slopes and stoniness. Populations of the cicada extend a few miles east of the distribution shown in Fig. 2, into Somerset County as far as Belle Meade.

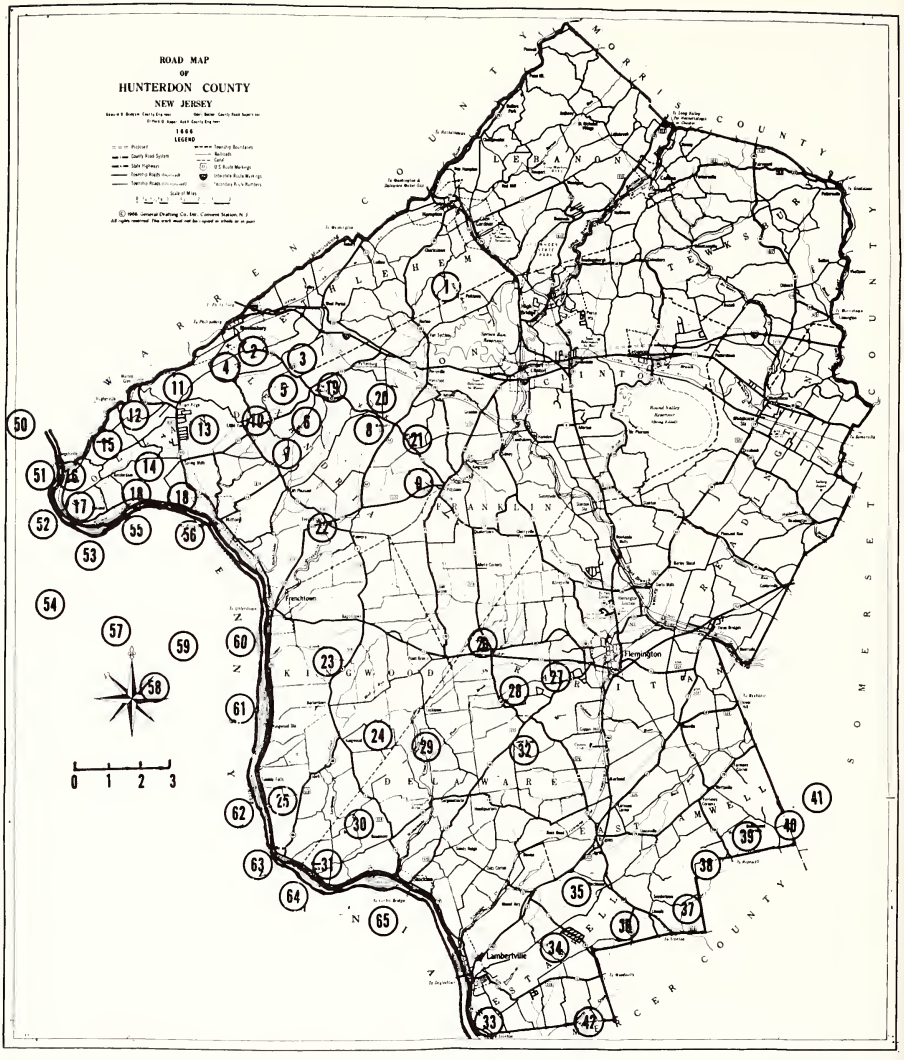

FIG. 2. Map of Hunterdon County and adjacent areas showing distribution of Brood X in 1970. See text for details.

The western boundary of Hunterdon County, along the Delaware River, is in most places a steep escarpment, usually wooded. Smith described the 1902 emergence along the river in these words: "Running south along the Delaware, the Warren County area of infestation extends into Hunterdon County and for its full length. It is broken, of course, at several points, notably at towns and settled areas, but practically the ridge back of the river is all cut by the Cicada." (His expression "cut by the cicada" refers to oviposition injury to trees.)

In 1970, very little cicada activity could be found along this same route. South of Milford, only three populations were found. One of these, No. 25, was found one mile north of Byram, and another, No. 31, was at Raven Rock but no other evidence could be found of the extensive emergence described by Smith as occurring between Raven Rock and Tumble Falls. The third population, No. 33, was found at Goat Hill, on the Hunterdon County line, at the end of the Sourland outcrop.

The total list of Hunterdon county localities is as follows (Fig. 2):

Hunterdon County Localities
Figure 2

No. Locality

1. Musconetcong Mountain, north of Polktown
2. Musconetcong Mountain, route 41, 1 mile south of Bloomsbury
3. Ridge, 3 miles south of Bloomsbury, on the Pattenberg-Bloomsbury road
4. Musconetcong Mountain, portion known as "Bloomsbury Mountain"
5. Ridge, west of route 579
6, 7. Along township road, south of Hickory Corner
8. West of route 579 at Mechlin's Corner
9. One mile west of Pittstown
10. Little York
11. Musconetcong Mountain, north of Riegel Ridge
12. Musconetcong Mountain, on the south side of route 519
13. East of route 519, between Riegel Ridge and Spring Mills
14. One mile west of Spring Mills, off the Amsterdam road
15. Musconetcong Mountain, Finesville (Warren County)
16. Along Delaware River, Musconetcong Mountain (Mt. Joy)
17. Along Delaware River, Musconetcong Mountain (Riegelsville Curve)
18. Along Delaware River, Milford-Holland road, continuous for 1 mile
19. Hickory Corner, east side of route 579
20. East side, route 579, north of Mechlin's Corner
21. East side, route 579, Mt. Salem
22. Everittstown, south side of route 513
23. Kingwood Township, route 519, 2 miles south of Baptistown
24. Kingwood Township, east of route 519, along Kingwood-Locktown Road
25. Along Delaware River, 1 mile north of Byram
26. Croton, north of state highway 12
27. Hardscrabble Hill, 2 miles west of Flemington
28. Route 579, 2 miles south of Croton
29. One mile south of Locktown
30. East of route 519, 1 mile north of Rosemont
31. Along Delaware River at Raven Rock
32. Route 523 at Sand Brook
33. Along Delaware River at Goat Hill
34. West of Hunterdon Hills Regional High School
35. West of Rocktown
36. West of Linvale, 1 mile
37. West of route 518, Snydertown road

38. On the Mercer County line, west of the Wertsville-Hopewell road
39. One mile west of Buttonwood Corners
40. On the Mercer County line, Wertsville-Zion road
41. Zion (Somerset County)
42. On the Mercer County line, one mile west of Harbourton

Although Smith's map of the 1902 emergence bears some discrepancies with his text, it is clear that the extent of Brood X distribution in the Warren-Hunterdon-Mercer-Somerset region has been greatly reduced in the intervening 68 years. Whether the remaining populations have much prospect for continued existence is an interesting question. Since the Delaware River is no more than one hundred yards wide at Frenchtown, and becomes much narrower upstream, there is some possibility that future reestablishment from Pennsylvania might occur if ecological conditions permit, in the event of the loss of the Hunterdon populations. Accordingly, several field trips were made to scout for cicada populations within five miles of the river in Pennsylvania. In a single day of field work, 16 populations were found, shown on Figure 2 as follows:

Pennsylvania Localities:

50. Raubsville
51. Riegelsville (Pa.)
52. Durham Furnace (ruins)
53. Kintnersville
54. Ferndale
55. Opposite Holland, N. J.
56. Upper Black Eddy
57. Tohickon Park
58. Ralph Stover State Park
59. Erwinna-Ottsville road
60. Tinicum Park
61. Stover Mills
62. Lumberville
63. Opposite Byram, N. J.
64. Opposite Raven Rock, N. J.
65. Solebury

The extension of Musconetcong Mountain into Pennsylvania, sometimes called the "Reading Prong," was reported by various correspondents to be heavily populated by the cicadas, but no effort was made to determine their distribution at points more than five miles from the river.

DISCUSSION

In 1902, Smith gathered his information on the distribution of periodical cicada populations in three ways: (1) by general and professional correspondence, (2) from the reports of 127 "official crop correspondents" scattered throughout the state, and (3) by his own travels, chiefly by railroad. In 1970,

the relative ease of gathering information by automobile and the generous help of colleagues and county extension agents, as well as many letters from the general public, made the writer's undertaking both a much easier task and, presumably, a more thorough one. From the compared data it is at least clear that a very marked reduction in the number of Brood X populations has taken place between 1902 and 1970. This reduction involves both the loss of isolated populations and a considerable reduction in the extent of the regional distribution now centered in Hunterdon County.

With respect to these losses, it is of some interest to consider a statement made by Marlatt (1898): "The greatest check on the species has been the advent of European man on this continent and the accompanying clearing of woodland and the increase of settlement. The vast areas in the more-densely populated East which were once thickly inhabited by one or the other of the broods of the periodical cicadas, are rapidly losing this characteristic and the Cicada will doubtlessly appear in fewer and fewer numbers in all settled districts." Marlatt illustrated this prophecy with an account of the fate of Brood XI in the Connecticut Valley,which appeared in great abundance in 1869, but seemed doomed to virtual extinction by 1903 "as a result of the steady reduction of woodlands."

Some of the loss of Brood X in New Jersey since 1902 was very probably due to man's direct interference, especially in Mercer and Somerset. The loss of woodlands for agricultural use, however, has probably not been significant. Rather, the development of homesites, especially as large-scale undertakings, would appear to have been a more likely cause. Smith believed that both domestic fowl and the English sparrow played a significant part in the extermination of some populations, especially in the case of isolated counties.

The situation in Salem County, where two 1902 populations appeared to have been lost, and two "new" populations were found in 1970, may involve nothing more than a relocation of the 1902 populations in the four-generation interval. Lloyd and Dybas (1966) point out that female cicadas are very prone to oviposit in the young trees of an advancing forest edge. Whether such a mechanism could result in such extensive relocations is not easily decided.

Perhaps future study of the Indian Mills population (Fig. 1, 9) may provide some information on this question. This population was found in woodlands about one-half mile from the boundary of the State-owned Wharton Estate and coextensive with the State lands. It is very unlikely that there will be any future human activity deleterious to the cicadas.

The future of the Hunterdon County populations can be speculated upon only with considerable uncertainty. The three populated regions described in this paper (the Musconetcong Mountain and ridge area, the Hunterdon plateau, and the Sourlands outcrops) offer so little advantage to agriculture that further destruction of woodlands to that end seems unlikely. While there has been some home-building in all three regions, the pressure for home sites does not appear

to be very threatening. Also, a large part of the Sourlands area in Somerset County has been purchased and set aside as preserved land, and may permit the cicadas to endure in at least that much of the Sourlands.

Perhaps a more immediate threat exists in the destructiveness of another insect, the gypsy moth. Mr. John Kegg of the N. J. State Department of Agriculture has kindly supplied the writer with detailed maps of defoliation caused by the gypsy moth from 1971 through 1974. Past experience suggests that considerable loss of oak and other deciduous trees is likely to result from such defoliation after three successive years. The areas of heaviest defoliation in Hunterdon County correspond very closely with the greatest concentrations of periodical cicada populations (Fig. 2), but whether the cicada nymphs can survive such tree losses is uncertain.

Perhaps a more immediate evaluation of the possible impact of tree loss caused by gypsy moth defoliation on the periodical cicadas will be possible in 1979, when Brood II, the other major brood in New Jersey, would mature. Smith (1912) compiled fairly detailed records on the distribution of Brood II in 1911. The Wanaque Reservoir forests in Passaic County, an area heavily populated by Brood II of the cicadas, have been studied intensively by Mr. Kegg in an evaluation of gypsy moth activity, and have also, by virtue of being on a protected watershed, been fairly free of human activities detrimental to the cicadas. The fate of Brood II in this area in 1979 may therefore be of special interest in determining the impact of tree loss caused by the gypsy moth on the periodical cicada.

Apart from the possible effect of the gypsy moth on the Hunterdon County cicada distribution, it should be of interest to determine in 1987, 2004, 2021, *et seq.* what happens to the Hunterdon populations. It was primarily with the hope of providing a basis for such determinations that the writer sought to locate each Hunterdon population, although it must be admitted as quite possible that some populations were missed. At any rate, the behavior and ecology of an insect species with a 17-year life cycle offers an interesting challenge to the human species.

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BOOK REVIEW

Tissue Culture: Methods and Applications. Paul F. Kruse, Jr., and M. K. Patterson, Jr., eds. Academic Press, New York. 868 pp. $22.00.

This book describes the uses of tissue culture in a wide variety of disciplines. Entomologists will be particularly interested in Imogene Schneider's chapters, "Dipteran embryos and larvae (Diploid lines)" and "Characteristics of insect cells," E. P Marks' "Cockroach and grasshopper embryo tissue," and Arthur E. Greene and Jesse Charney's "Invertebrate cell cultures." In addition, such chapters as Leonard Hayflick's "Screening tissue cultures for mycoplasma infections" and Michael F. Barile's "Mycoplasma contamination of cell cultures: Incidence, source, prevention, and problems of elimination" are of pertinent interest to all engaged in attempting to grow insect cells and tissues *in vitro*. More than 100 authors contributed to this volume; it should serve as a reference source for both experts and beginners using tissue culture for years to come. Its usefulness as a guide is enhanced by a detailed author and subject index, totaling 39 pages. Excellent illustrations of cultured cells and karyotypes, as well as of specialized equipment, add to the value of this book.

Karl Maramorosch